ORIGIN OF PETROLOGICAL AND GEOCHEMICAL ZONING IN THE RONDA PERIDOTITE VIA THERMAL AND CHEMICAL EROSION OF SUBCONTINENTAL LITHOSPHERIC MANTLE BY UPWELLING ASTHENOSPHERE

Xavier Lenoir*, Carlos J. Garrido*, Jean-Louis Bodinier*, Jean-Marie Dautria* and **Fernando Gervilla****

** Institut des Sciences de la Terre, de l'Eau et de l'Espace, UMR 5568, CNRS and Université de Montpellier 2, Case 49, Place Eugène. Bataillon 34095 Montpellier cedex 05, France.*

*** Instituto Andaluz de Geologia Mediterranea, CSIC and Universidad de Granada, Fuentenueva s/n, 18002 Granada, Spain.*

ABSTRACT

A well-know characteristic of the Ronda peridotite massif (S Spain) is the existence of a km-scale structural (Van der Wal and Vissers, 1996), petrological (Obata, 1980) and geochemical (Frey at al., 1985; Reisberg et al., 1989) zoning. From N-NW to the S-SE, three structural domains of decreasing ages have been recognized by Van der Wal and Vissers (1996): (1) a *spinel-tectonite* domain made of porphyroclastic spinel peridotites, garnet-spinel peridotites and subordinate garnet pyroxenites, representing old, veined lithospheric mantle (Reisberg et al., 1989, 1991); (2) a *granular peridotite* domain composed of coarse-grain spinel peridotites and subordinate spinel websterites, both derived from spinel tectonites via open-system recrystallization at shallow depth (Van der Wal and Bodinier, 1996; Garrido and Bodinier, 1999); (3) a *plagioclase tectonite* domain, the youngest of the three domains, composed of porphyroclastic plagioclase peridotites related to crustal emplacement of the massif (Van der Wal and Vissers, 1996). Compared with the petrological zoning identified by Obata (1980), these three domains correspond respectively to the (1) garnet lherzolite facies and ariegite subfacies, (2) Seiland subfacies and (3) plagioclase lherzolite facies.

One of the most striking features of the massif is the transition from the spinel tectonite to the coarse-grained peridotite domain. This transition occurs across a narrow recrystallization front ($\leq$ 400 m) where major microtextural, trace-element and isotopic variations take place in peridotites and pyroxenites (Van der Wal and Bodinier, 1996; Garrido and Bodinier, 1999). The recrystallization front is roughly vertical and can be followed over a distance of more than 20 km. It has been interpreted by Van der Wal and Bodinier (1996) as a magmatic permeability barrier for basaltic melts accumulated in the granular domain. At regional scale, the development of the front was probably connected with a recent thermal event in the Alboran domain, ascribed to upwelling of asthenospheric mantle after gravitational collapse of thickened continental lithosphere. Hence, the Ronda recrystallization front provides a unique opportunity to study asthenophere-lithosphere interactions associated with mantle upwelling.

The aim of this study was twofold: (1) evaluate the lateral continuity of geochemical variations across the front, and (2) investigate whether the recrystallization was associated with a thermal event registered by mineral compositions. 40 peridotites collected along several sections across the front were analyzed by ICP-MS for trace elements. Orthopyroxene and clinopyroxene pairs were analyzed by electron microprobe. In addition, these minerals were separated from 6 samples and analyzed by ICP-AES to estimate equilibrium temperatures while avoiding compositional variations produced by pyroxene exsolution.

Most of the analyzed peridotites display LREE-depleted normalized patterns. Yet, a systematic difference is observed for Ce_N/Sm_N (= chondrite-normalized Ce/Yb ratio) across the recrystallization front, the granular lherzolites being systematically more LREE depleted ($Ce_N/Sm_N < 0.5$) than equivalent rock types in the spinel tectonite domain. These data confirm that the front represents a major geochemical discontinuity in the Ronda massif and was developped in open system. Likewise, the equilibrium temperatures measured with the two-pyroxene thermometer of Brey and Kholer (1990) are significantly higher in the granular peridotites (1190-1220°C) than in the spinel tectonites (1070-1090°C).

The higher temperature obtained for the granular peridotites suggests that the driving force of recrystallization was thermal in origin. In addition, independant field and geochemical constraints on melt processes indicate that a significant temperature gradient existed across the Ronda massif during the development of the recrystallization front. In the granular domain, evidence for partial melting and pervasive interaction with basaltic melts implies temperatures above or close to the peridotite solidus. About in the meantime, the spinel tectonites were traversed by low-temperature, volatile-rich small melt fractions similar to those inferred for diffuse cryptic metasomatism in subcontinental lithosphere (Bedini et al., 1997). The outermost parts of the spinel tectonite domain were even cut by intrusive dikes (Garrido and Bodinier, 1999).

However, considering that the recrystallization front is < 400 m wide, the temperature difference measured in our samples (100 - 125°C) would imply an unreallistically steep geothermal gradient (ca. 200°C / km). Hence, the observed difference is more likely of kinetic origin. Since diffusion in solids is orders of magnitude slower than diffusion in melts, the higher melt-rock ratios inferred for the granular peridotites, together with the dissolution-crystallization process, probably led to faster mineral reequilibration in this domain, compared with the spinel tectonites. In order to preserve a fossil recrystallization front and differences in equilibrium temperatures across the front, the thermal event must have been relatively short-lived. The kinetic interpretation requires that the time scale of heating was intermediate between the critical time of diffusion in solids and that of melt-enhanced inter-granular diffusion and recrystallization. Since the thermal event occured in a very late stage of the

massif evolution, it has probably aborted due to fast crustal emplacement of the massif by extensional tectonics.

A corollary of the above discussion is that thermo-mecanical and magmatic processes are probably coupled during lithosphere-asthenosphere interaction. This relationship has not being considered in pure thermo-mechanical models of lithospheric erosion. Yet, feedback relationships between melt accumulation and olivine grain growth can cause a substantial drop in the viscosity of peridotites and create a km-scale weak layer at the base of the lithosphere. Mechanical erosion of such layer by the convective mantle will trigger a new cycle of thermal and chemical erosion of the lithosphere.

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